THE INTEGRATION OF THE PCM INTO LEIGHT WEIGHT BUILDING WALLS: PARAMETRIC STUDY

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Résumé

Phase change materials (PCMs) used in the building walls constitute an attractive way to reduce the energy consumption and to increase the thermal comfort of the occupant. In this work, the potential of Phase Change Materials (PCM) wallboards, is evaluated experimentally. The experimental study is conducted in a heated reduced scale cavity including walls with or without PCM in a laboratory conditions. The cavity is composed of removable and exchangeable walls to discuss several configurations with or without PCM. The test cell dimensions are 0.4m x 0.4m x 0.4m. The effect of the location and the double PCM layer is conducted in term of wall surface temperature. An interesting results are presented and discussed in this paper.

Mots clefs: *Experimental study, PCM integration, reduced scale cavity.*

1. Introduction

In modern architecture buildings trend to be designed by using lightweight materials. This makes that some of them have a lack of thermal mass which may lead to low comfort and energy efficiency levels [1]. Scientists around the world are looking for new ways to reduce the sector's energy consumption of the building and thereafter the reduction of CO2 emissions.

One promising way to improve the thermal inertia of a building is to integrate PCM layers in its envelope. The utilization of microencapsulated paraffin in plaster represents a recommendable application. However, there are some design challenges to be faced when the PCM is integrated into building. The critical one is the incorporation method. Several authors highlight the various promising approach to incorporate the PCM into building construction. In the updated reviews, Yeliz Konuklu et al. [3] and D. Zhou et al. [4], summarize the techniques on how the PCM is integrated into building construction. The first one in which the PCMs can be integrated by direct incorporation, immersion or macroencapsulation. These methods are easy to manipulate, however, the leakage phenomena is the biggest problem which is not good for long-term use. The second method is the microencapsulation, which is the most suitable for thermal energy storage of buildings.

In this study, an investigation of the thermal behavior of a cubic model with composite walls (PCM and wood) is done. The model thus defined (the cavity at reduced scale) is placed in a room where the temperature is controlled. The originality of our work is in the control of the boundary conditions and achieving steady state. The effect of placement and layer thickness of the PCM layer within the wall, are studied in details.

2. Experimental set-up

The PCM used in this study is an Energain/Dupont product in the form of a panel consists of two sheets of aluminum 75 microns thick containing a solid component of copolymer (ethylene, 40%) and paraffin (60%). Properties of this PCM are shown in the Table1.

The experimental tests were performed using cavity at reduced scale termed here as “test cell”. It is composed of removable and exchangeable walls to discuss several configurations with or without PCM. The test cell dimensions are 0.4m x 0.4m x 0.4m. One of its vertical walls is simple glazing. The other walls are wooden walls with or without a PCM layer.

Table 1: Thermal properties of PCM.

Melting temperature (paraffin)	*21.7°C -31 °C*
Latent heat of fusion (0°C - 30°C)	*> 70kJ/kg*
Total heat storage capacity (Temperature range 0°C to 30°C)	*~ 140 kJ/kg*
Thermal conductivity (solid phase)	*0.18 W/(m.K)*
Thermal conductivity (liquid phase)	*0.14/(m.K)*

3. Results and discussion

3.1. Optimal location for the PCM layer

PCM location within walls affects phase change process and it is critical for the optimum thermal performance of walls outfitted with PCMs. In this section, the thermal performance of PCM location is studied, under the configuration 1:

- Wall 1: single glass;
- Wall 2: 1.5cm wood / 0.5cm PCM / 2cm wood;
- Wall 3: 0.5cm PCM / 3.5cm wood;
- Wall 4: 4cm wood.

Fig.1 shows the evolution of the indoor and outdoor air temperatures of the cavity on two cycles of 9 hours each (5 hours of heating and 4 hours of cooling).

In the first minutes, the heating demand rises very quickly (transient) until the permanent regime after only a few minutes of heating. This is because of the little cavity volume, thereby minimizing its thermal inertia and internal convective exchanges. Note that the outdoor temperature (the inside temperature of the local scale 1) is fixed at 20°C (set point). Throughout the heating period, the PCM store, by fusion, a part of heat that would leave the cavity in the form of heat losses to the outside. After five hours we stopped heating. The indoor temperature of the cavity decreases in a hyperbolic manner until thermal equilibrium.

Fig.2 shows the exterior surface temperature of the vertical walls. It can be seen that the two curves of wall 2 and wall 4 are virtually identical. This can be explained by the fact that the temperature boundary layer of the PCM between two wooden plates, is almost around 21°C. Therefore the PCM is still in the solid state having a thermal conductivity close to that of wood and therefore it is with no role. However, the wall 3 can reduce a huge heat flux because the PCM layer is in direct contact with the indoor hot air for which the temperature is around 35°C and therefore the melt storage process is primed.

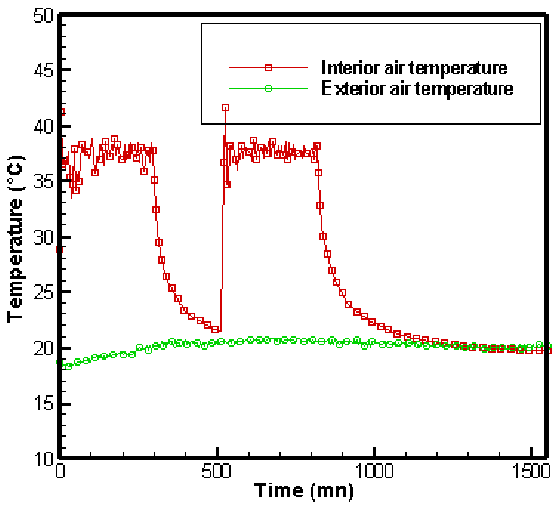

Fig.1: Indoor and outdoor air temperature, configuration 1.

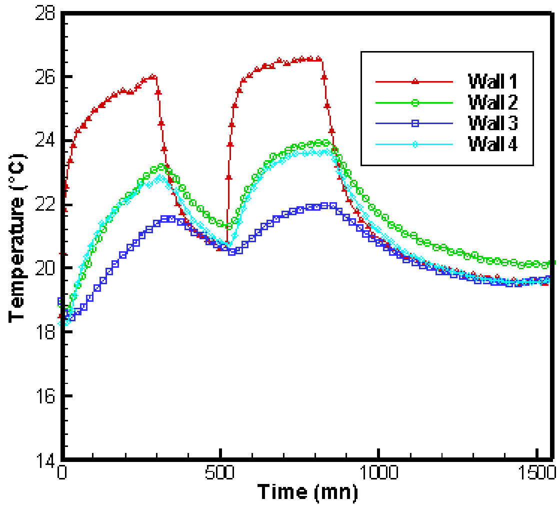

Fig.2: Exterior surfaces temperatures, configuration1.

3.2. Effect of double PCM layer

In this section, another configuration is presented to study the effect of double PCM layer concept. The configuration 2 is as below:

- Wall 1: double glazing;
- Wall 2: 0.5cm PCM / 3.5cm Wood;
- Wall 3: 1cm PCM / 3cm Wood;
- Wall 4: 4 cm wood.

In Fig.3, we show the evolutions of the indoor and outdoor air temperatures of the reduced cavity. Note that the outside temperature (the inside temperature of the local scale 1) is fixed at 20°C (set point). But as shown in Figure 2, it varies around 15°C because of the thermal losses from the local scale 1 to outside.

Fig.4 shows the exterior surface temperature of the vertical walls. Based on the Fig.4, the outside surfaces temperatures of the four walls. In the heating phase, it can be clearly seen that PCM walls (wall2 and wall3) can reduce significantly the outside surface temperature. Indeed, a further reduction is shown in the wall with double PCM layer (wall3).

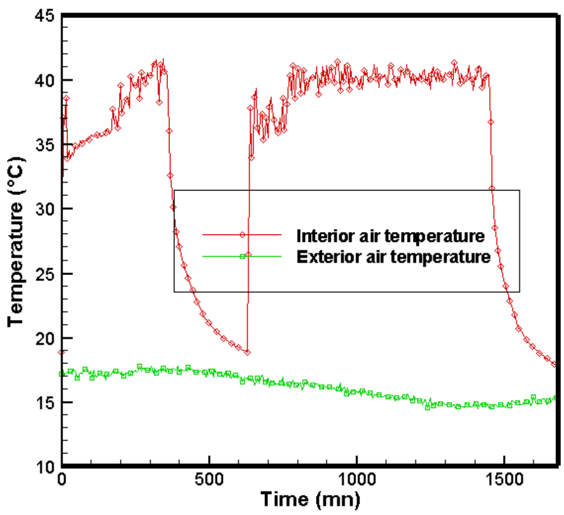

Fig.3: Indoor and outdoor air temperature, configuration 2.

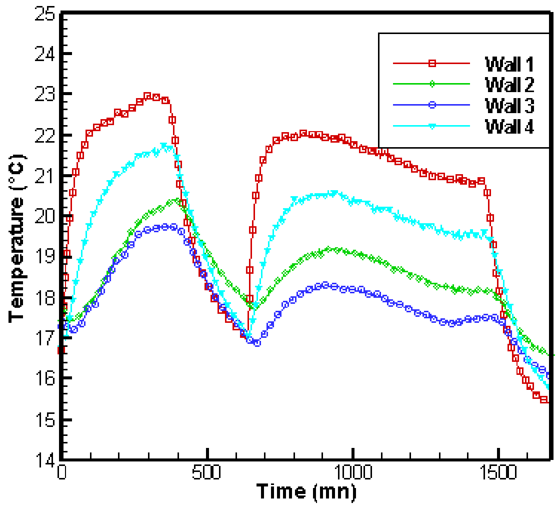

Fig.4: Exterior surfaces temperatures, configuration2

4. Conclusion

The feasibility of the PCM integration in the building walls to reduce the absorbed heat flux and surface temperatures in a reduced scale cavity is investigated experimentally. The experimental set up is built using a light weight cavity at reduced scale. The results show that, the location of the PCM layer close to the heat source reduce significantly the wall surface temperature. Indeed, it is showed that, the double PCM layer reduce also the wall surface temperature.

Références

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